Habitat Enhancement Project Update
10/16/06

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Introduction:
As a means of providing mitigation for the assumed biological impacts of the HubLine construction, *MarineFisheries* enhanced key bottom sediments in Massachusetts Bay. A substantial amount of the impacted sediment along the pipeline footprint was comprised of hard bottom habitat, a habitat type that cannot be easily restored to its original state upon completion of construction. This type of habitat is critical to several life stages of commercially important species such as American lobster, winter flounder, sea scallops, sea urchins, Atlantic cod, and numerous other species of fish and invertebrates (Wahle and Steneck 1992, Tupper and Boutilier 1995, Johnson et al. 1999, Packer et al. 1999, Pappal et al. 2004). This substrate type exhibits surficial complexity which provides the relief and interstitial spaces necessary to shelter cryptic species such as lobster and juvenile finfish (Cobb 1971, Dixon 1987, Wahle 1992, Dorf and Powell 1997, Tupper and Boutilier 1995 and 1997, Pappal et. al. 2004). Numerous other species of fish and shellfish such as Atlantic herring, ocean pout, and Atlantic wolffish also find refuge in cobble/gravel habitat areas during vulnerable early life stages (Tupper and Boutilier 1997). Sessile invertebrates, important to the productivity and diversity of an area, also are dependent on complex hard bottom. *MarineFisheries* was obligated to provide appropriate mitigation for any perceived impacts to these aquatic resources that were potentially related to HubLine construction activities. As mitigation for the assumed impacts from hard bottom habitat loss, this project provided variable-sized rocks in order to target different life history stages of invertebrate and finfish species.

The habitat enhancement project consists of four phases: (1) experimental design, (2) site selection and permitting, (3) installation, and (4) monitoring. Currently, *MarineFisheries* has completed the first three phases of this project and started the fourth stage, or the monitoring section of the program.

Activities Update:
MarineFisheries continued its site selection process throughout the 2005 field season for the placement of a cobble/boulder reef. After the initial elimination process outlined in the July 7, 2005 Project Update (see Project Update section on webpage for this report), we reduced our original 24 potential sites down to 14 potential sites.

All 14 remaining potential sites were within 6.8 miles of the nearest harbor and in the 20 to 50 ft. MLW depth range. Therefore, all potential sites were considered accessible to recreational and commercial fisherman, scientists, recreational SCUBA divers, and other interested user groups. No sites were located within shipping channels marked on NOAA charts. Additionally, *MarineFisheries* discussed the habitat enhancement project with the Massachusetts Lobstermen's Association to avoid potential conflicts with commercial lobstermen. No other commercial fishing activities were expected to occur in the vicinity of potential sites due to existing shellfishing closures and shallow, undesirable depths for large-scale fishing practices such as trawling.

We then conducted underwater transect surveys (Figure 1) on the 14 remaining sites in order to determine the stability of the substrate and to classify and quantify the substrate into three main categories: primary substrate = the substrate type that constitutes more than 50% of the area, secondary substrate = the substrate type that constitutes between 10-50% of the area, and underlying substrate = the substrate type found underneath the primary and secondary substrate. Additional biological and physical data was collected including: species presence and/or absence and current direction. These data were used in the site selection process to avoid placing the reef on pre-existing productive habitat and ensured that the reef would be placed on substrate that we expected to be strong enough to prevent reef sinking.

Figure 1: Diver conducting transect survey

Upon completion of these transect dives, one more site was eliminated and one of the alternative sites was substituted, leaving 7 potential sites in Boston Harbor and 7 potential sites in Salem and Marblehead (Figure 2 & 3). In order to rank the remaining potential sites, *MarineFisheries* developed a weighting system to incorporate different aspects of the site selection criteria. Data used in this portion of the analysis included the primary substrate, secondary substrate, underlying substrate, sand ripple presence (an indicator of wave action), site proximity to the HubLine, and site proximity to cobble fill points along the HubLine.

We followed a six step approach to this analysis (each step will be explained in detail following this list):

1. For each site, every data category received a numerical score from 1 (poor site potential) to 3 (prime site potential)
2. A percentage value was assigned to each data category according to its importance in the site selection process
3. The numerical scores were "weighted" by multiplying the final score for each data category by the category's assigned percentage
4. Final weighted scores from every data category were summed for each site
5. Sites were ranked, where sites with the highest scores met all necessary physical attributes for the site selection
6. Qualitative species presence/absence data were taken into account following the ranking analysis in the final site selection process.

Site Scoring:

For each site, we assigned a numerical score to every data category based upon how well the site met the selection criteria. We used three numerical values to represent (3) prime, (2) potential, or (1) poor suitability for reef placement. The following methods were used to assign these scores to the data:

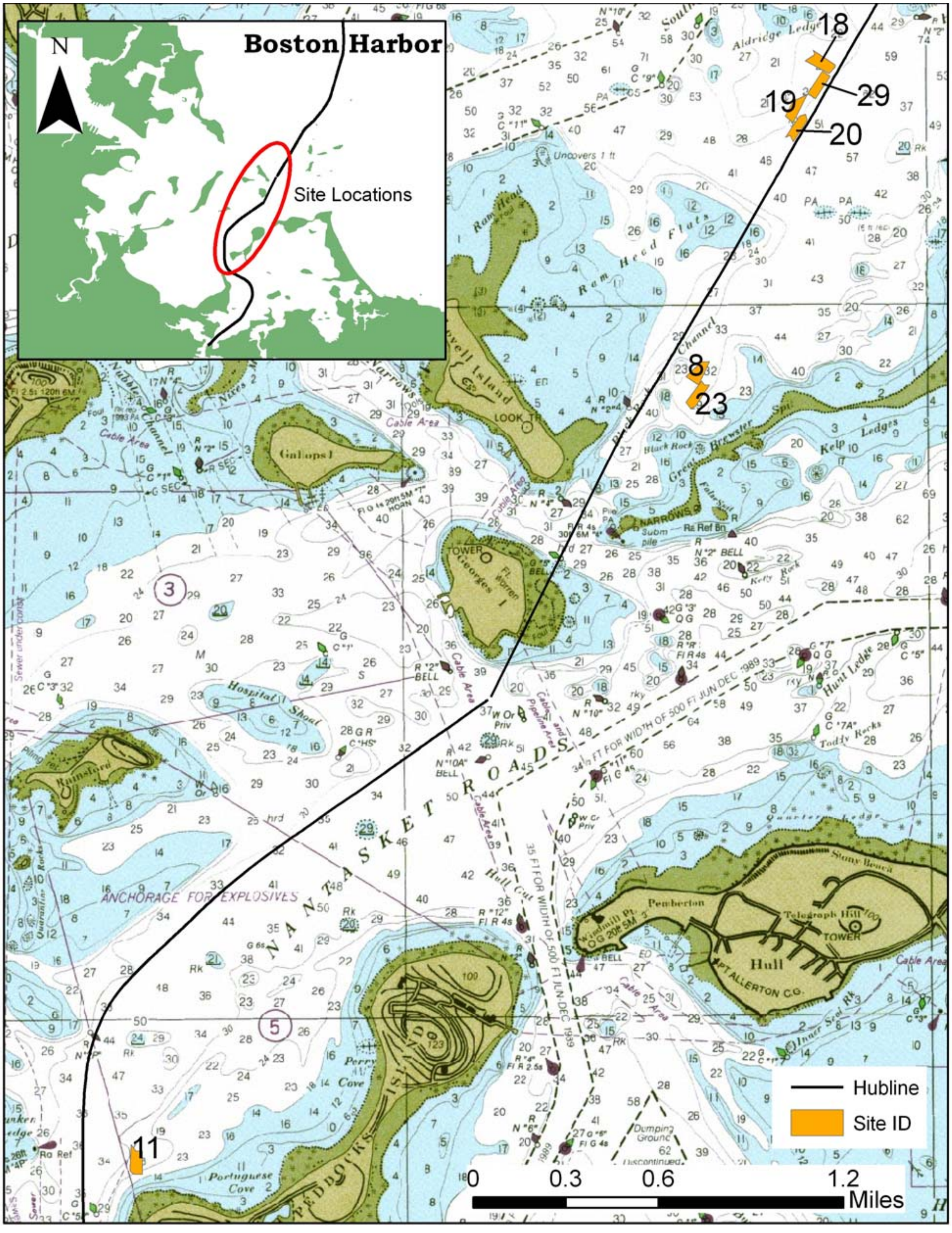

Figure 2: Location of the seven potential sites in Boston Harbor

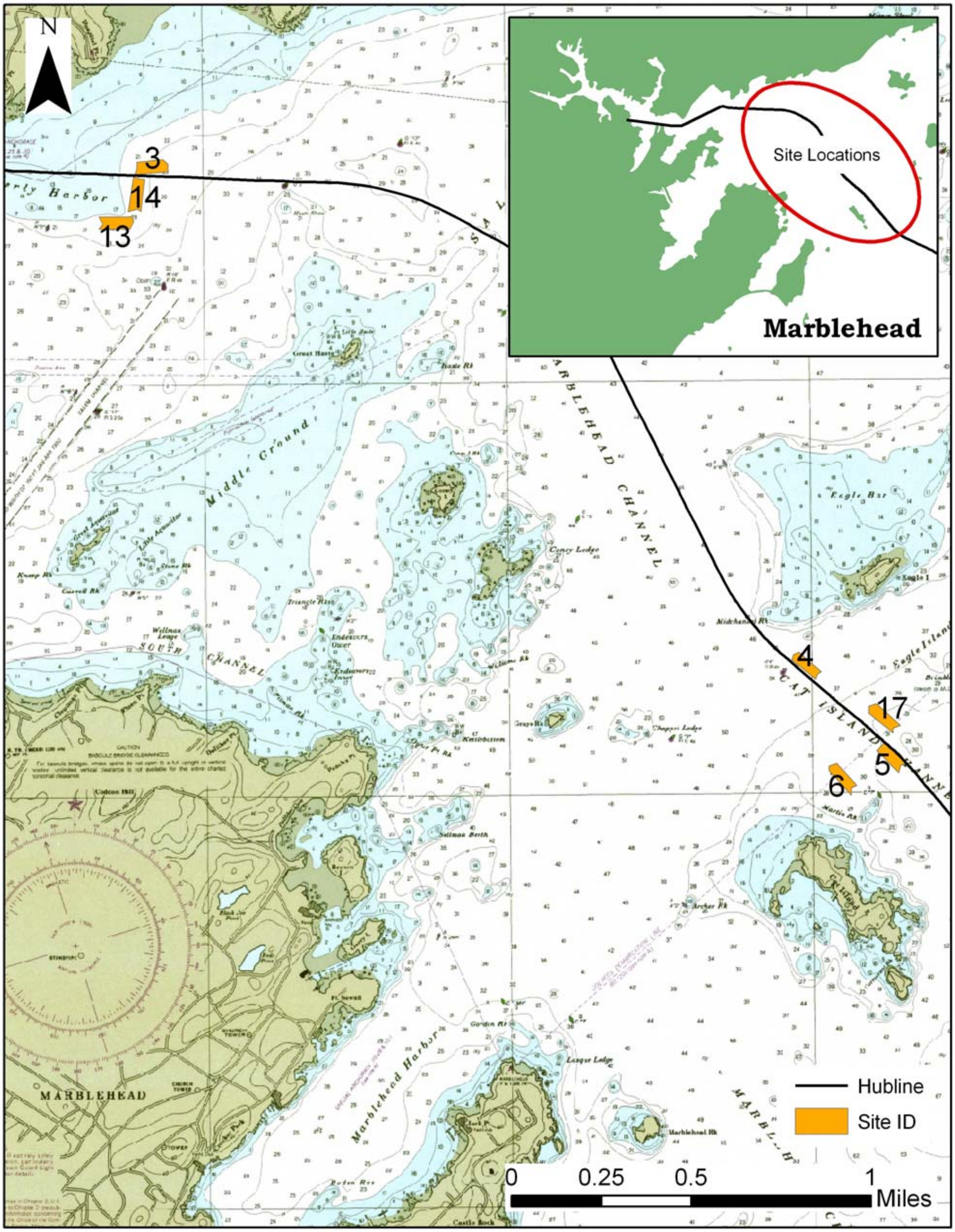

Figure 3: Location of the seven potential sites in Marblehead and Salem

A. Sediment Rating: Each site was classified by the percentage of all sediment types recorded in the area for the primary, secondary, and underlying categories. The sediment categories included boulder, cobble, pebble, granule, sand, shack (whole shells), shell debris, and silt. Sites with pebble, granule, sand, shack, or shell debris were preferred because these substrate types are usually strong enough to support the weight of a reef and naturally support lower species diversity than cobble or boulder. All sediment types were broken down into the following numerical categories in order to describe their suitability for reef placement.

Category rating levels:
1 = Poor: boulder, cobble and silt
2 = Potential: mixed flat cobble
3 = Prime: pebble, granule, sand, shack, and shell debris

Each sediment proportion was multiplied by the assigned category rating of 1, 2, or 3. These values were then summed to provide a final sediment score for that data category. For example, if a site had 70% pebble and 30% boulder as primary substrate, the following calculation was performed for the final primary substrate score: (0.70*3) + (0.30*1) = 2.4.

The same sediment rating analyses were conducted for secondary and underlying substrates.

B. Sand Ripple / Wave Action: We assumed that the presence of sand ripples on a site indicated areas of high wave energy which may be detrimental to reef placement. Therefore, sites were classified as either (3) low energy = no sand ripples, (2) moderate energy = small sand ripples (1-5 inch height) or (1) high energy = large sand ripples (> 5.1 inch height).

C. Proximity to HubLine: Sites that were closer to the HubLine were preferred. Therefore, sites were classified as either (3) adjacent to the HubLine pathway (< 100 ft.), (2) near the HubLine (100-499 ft.), or (1) far from the HubLine (500-1000 ft.).

D. Proximity to Fill Points: Sites that were closer to fill points were preferred. These cobble fill points along the HubLine were considered to be areas that were highly disturbed by the installation of the HubLine. Sites were classified as either (3) adjacent to a fill point (< 100 ft.), (2) relatively near a fill point (100-499 ft.), or (1) relatively far from a fill point (> 500 ft.).

Assigning the Scale:
Each variable described above was weighted on a percentage scale according to their importance in the site selection process. *MarineFisheries* developed an objective weighting system based on the relative importance of the selection criteria to the project objectives (Table 1). The primary substrate variable was assigned the largest weight at 50% because this was the substrate that would be directly impacted by the installation of the reef and the sediment that would need to carry the majority of the reef's weight. If the potential site had a high percentage of productive habitat (i.e. "poor" reef substrate) this weighting category would automatically rank the site

much lower than a site with mostly "prime" reef substrate. The other two substrate categories were assigned weights of 15% to represent their importance in supporting the weight of the reef, as well as avoiding productive habitat. We assigned a weight of 10% to the presence of sand ripples as an indicator of wave action in the area. Although this variable was not as crucial as substrate, it was still important to take wave action into account in terms of its ability to dislodge or bury the reef. Finally, the proximity to the HubLine and fill points received 5% weighting to account for our goal to place the reef near these areas if all other site selection criteria were met.

Table 1: Weighting categories

Variables	Weight
Primary substrate	50%
Secondary substrate	15%
Underlying substrate	15%
Wave action	10%
HubLine proximity	5%
Fill point proximity	5%

Weighting and summing the scores:
Each numerical score from every reef and data category was "weighted" by multiplying the final score for each data category by the category's assigned percentage. Then the final weighted scores were summed for each site.

Ranking the sites:
The scores of all fourteen sites were ranked, where the sites with the highest scores met the necessary physical attributes for reef placement (Table 2). At this point we eliminated sites 17, 3, 14, and 13 due to the presence of large sand ripples or poor, silty substrate that would not be able to support the weight of a reef.

Table 2: Weighting results

Site Rank	Site ID
1^{st}	20
2^{nd}	29
3^{rd}	11
4^{th}	18
5^{th}	23
6^{th}	19
7^{th}	4
8^{th}	8
9^{th}	6
10^{th}	5
11^{th}	17
12^{th}	3
13^{th}	14
14^{th}	13

Accounting for species presence/absence:
Upon completion of the weighted ranking analysis, we still needed to consider biological factors at the potential reef areas. Therefore, we qualitatively included results from the species presence/absence data we collected on each transect dive. We reviewed our species notes from each site and looked at the number of species present on each site, standardized by the number of transects completed per site. Using this information we were able to determine what sites needed to be eliminated due to potentially high species abundance or diversity. We immediately eliminated Site 4 because it had very high relative species abundance and diversity. Site 11 was also eliminated because of high siltation rates and knowledge of poor lobster settlement in the region.

After these initial eliminations, we were ready to select six final sites. We had three separate areas in which we were considering placing the reef: Marblehead, Northern Boston Harbor, and Southern Boston Harbor. In our final site selection process, we decided to include 2 sites within each of these three areas. We felt that maintaining three separate areas gave us the flexibility we needed in case one of these areas did not meet all our site selection criteria. This decision proved to be valuable because we recorded much higher siltation rates in Southern Boston Harbor during the final weeks of our site selection process, and we needed to eliminate the area to avoid possible reef burial problems.

At this point we had sites 5 and 6 in Marblehead; sites18, 19, 20, and 29 (alternative site) in Northern Boston Harbor; and sites 23 and 8 in Southern Boston Harbor. Due to the fact that we wanted two potential sites per area, we eliminated site 19 from Northern Boston Harbor because it was the lowest ranking of the four sites. Site 29 in Northern Boston Harbor was not seriously considered for the final sites because it was strictly serving as an alternative site, to be used only if all other sites in the area failed to meet our site selection criteria.

Therefore, we selected the following six final potential sites: (1) Marblehead sites 5 and 6, (2) sites 18 and 20 near the Hypocrite Channel in Boston Harbor and, (3) sites 8 and 23 near the Brewster Spit in Boston Harbor. We then conducted video surveys at these six sites. Additional 140m transects were surveyed with the goal of assessing as much area as much as possible in the 1.7 acre footprints. This allowed *MarineFisheries* to assess the site's overall potential and species abundance and diversity. Following these dives, we eliminated Sites 5, 18, and 8 due to existing natural rocky habitat and higher species abundance and diversity. Therefore, Site 6 in Marblehead, Site 20 in Northern Boston Harbor, and Site 23 in Southern Boston Harbor were the three final sites selected for further consideration.

When these three site locations were sent to the MA Board of Underwater Archaeological Resources (BUAR) for review, Site 20 was deemed to be too close to an area of archeological concern. Therefore, Site 29 (the alternative site) was substituted for the highest ranking site, Site 20. We also completed the 140m transect dives on Site 29 and determined that it had very low species abundance and diversity. Therefore, the three final sites considered for the habitat enhancement project were sites 6, 23, and 29. General descriptions of each of these sites are included below.

Prior to collecting additional data on the three final sites, we analyzed our bottom water current data that we collected using the Dimond Design (see July 7, 2005 Project Update/Estrella 2005). The Dimond Design was created to record predominant current direction in the NS, WE, NE/SW, and SE/NW directions. Our goal was to orient the reef perpendicular to the predominant current direction, in order to enhance settlement opportunities for larvae traveling in the current.

Upon completion of this data collection, only one of our sites (Site 6 in Marblehead) needed to be rotated in order to have the reef positioned perpendicular to the current. This site was shifted and remained in consideration as a potential reef location. Due to a defective flowmeter unit, the initial data (Summer 2005) gathered using this method was not used in the site selection process. The flowmeter, however, will be used in the future to understand the rate of flow over the reef and to compare the artificial reef to natural reef areas.

Final Three Site Descriptions:

Site #6 in Marblehead was located adjacent to Cat Island outside of the shipping channel (Figure 4). The primary substrate at this site consisted of pebble, granule and sand. All three of these substrate types were targeted for potential reef installation because they tend to support lower species diversity and abundance than cobble and boulder. The secondary substrate on this site again consisted of sand, pebble, and granule with a small percentage of cobble (Figure 5). We were not concerned with the small amount of cobble as secondary substrate because it was not found in densities high enough to create the interstitial spaces necessary to support high species abundance and diversity. The underlying substrate of sand and granule was considered strong enough to support the weight of a reef. No species on this site were observed in abundances greater than 2-5 counts per 150 ft. transect. The only species seen of commercial concern were the sea scallop, rock crabs, and lobster, although only 2-5 individuals were counted in total for

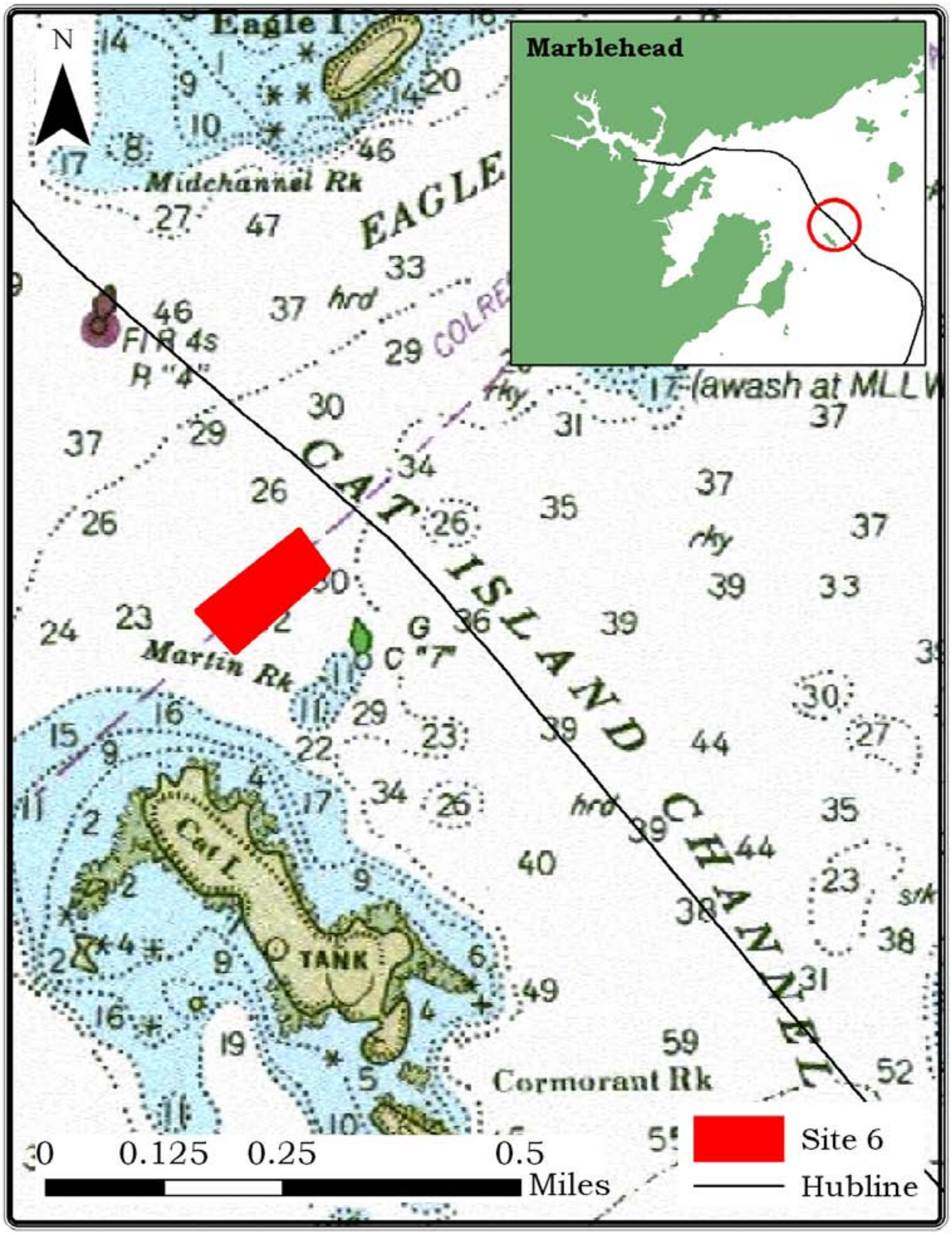

Figure 4: Location of Site 6 in Marblehead

each species. There was a fair amount of drift algae (unattached to substrate) on the site, most likely the result of a strong Nor'easter that hit the region a week before sampling. Species abundance and diversity on this site was lower than that of all other potential sites in the Marblehead region.

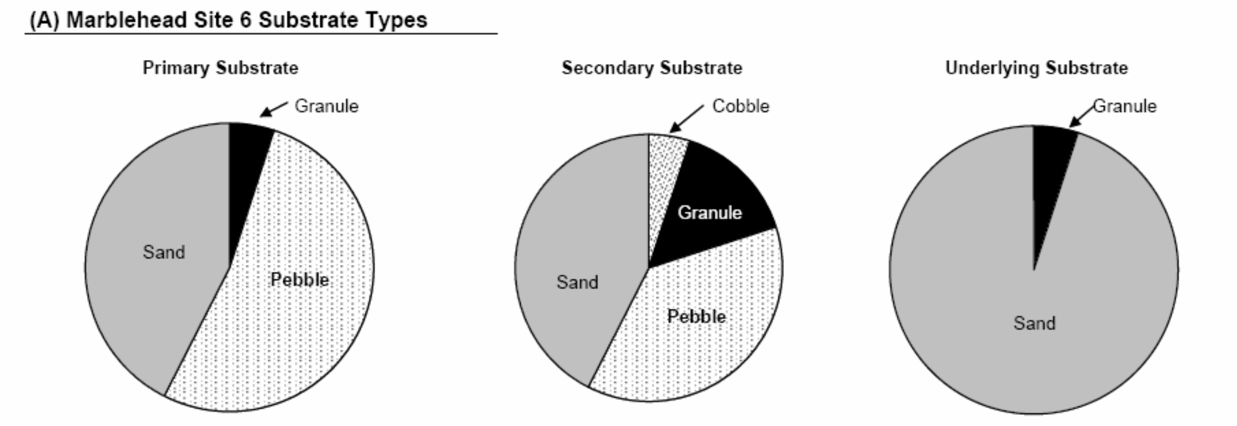

Figure 5: Substrate composition at Site 6 in Marblehead

Site #23 was located just north of the Brewster Spit in Boston waters off Lovell Island (Figure 6). The primary substrate at this site was pebble and sand with a small percentage of shell shack. The secondary substrate also met our criteria for site selection, consisting primarily of sand, shack and pebble with a small amount of cobble (Figure 7). Again, we were not concerned with the small amount of cobble as secondary substrate because it was not found in densities high enough to create the interstitial spaces necessary to support high species abundance and diversity. The underlying substrate of sand was considered strong enough to support the weight of the habitat enhancement area. Two species of non-commercially important invertebrates, the horse mussel (*Modiolus modiolus*) and hydroids were recorded in high abundance (100-200 individuals) along sections of our 150 ft. transect dives. Other species recorded in very low densities (no counts greater than 6-10 along 150 ft. transects) consisted of *Cancer sp*. crabs, razor clams, lobster, burrowing anemones, sea stars, moon snails, young-of-the-year sculpin, sea scallop, skates, spider crabs, and winter flounder. Algal coverage was <1% of all species noted on transects. Despite this site standing in the middle range of species abundance when compared to other sites, its species diversity was so low that this site was placed higher in preference than other sites in Boston near the Brewster Spit.

Site #29 in Boston was located just east of Lovell Island and just south of the Hypocrite Channel (Figure 6). The primary substrate consisted of sand and pebble and a small amount of granule. The secondary substrate was mostly pebble or sand with a small percentage of cobble and granule (Figure 8). Again, the cobble recorded here was not found in densities high enough to create substantial interstitial space and was, therefore, not expected to support high species abundance and diversity. The underlying substrate of sand was considered strong enough to support the weight of the reef. Although it contained more cobble than the original site for which it was substituted (Site 20 had 0% coverage of boulder or cobble), Site 29 still met our site selection criteria and ranked second highest among all our final sites of consideration. Site 29 was also located directly adjacent to a highly impacted area of the HubLine where cobble fill was

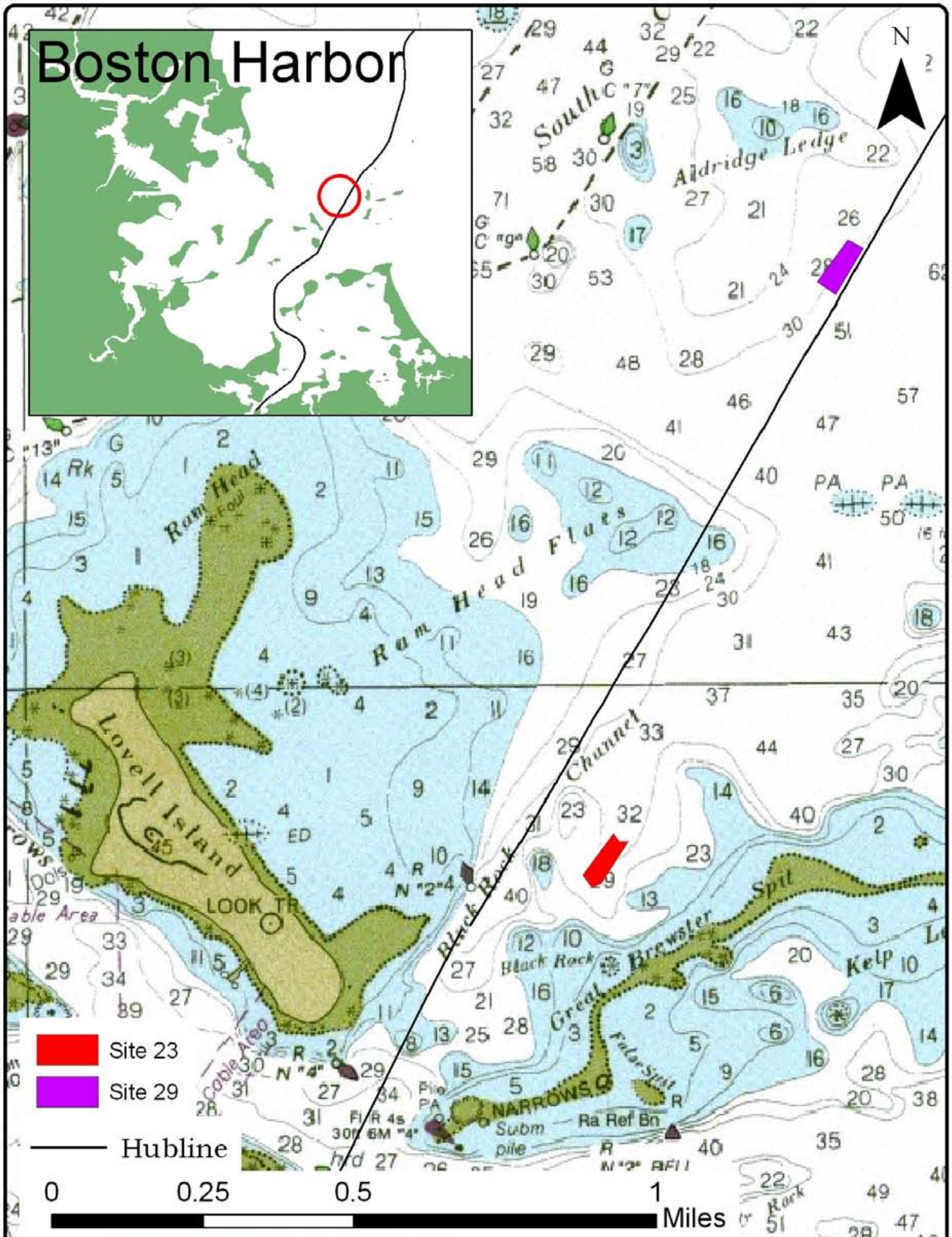

Figure 6: Location of Site 23 and Site 29 in Boston Harbor

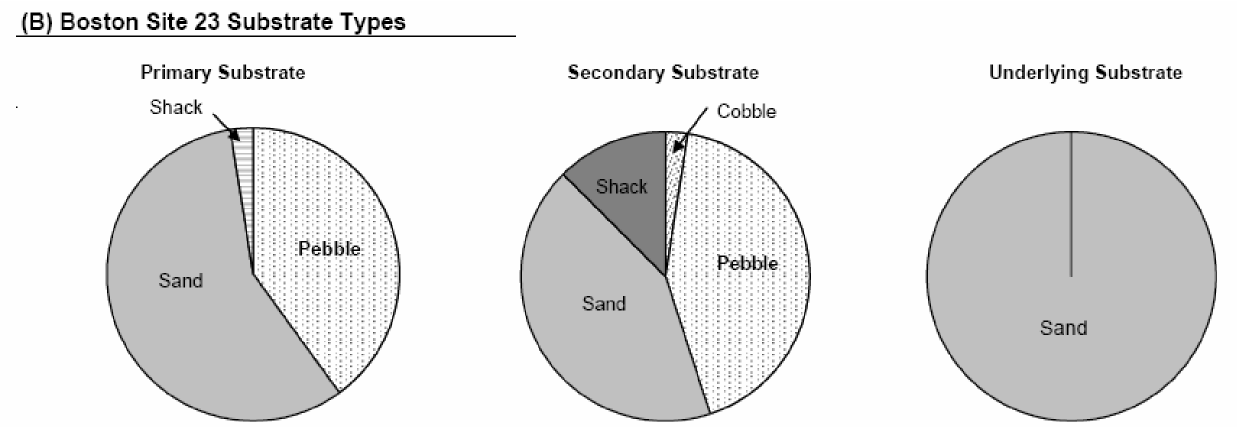

Figure 7: Substrate composition of Site 23 in Boston Harbor

placed. When compared to other sites, species abundance and diversity were among the lowest at Site 29. Species that were noted in densities of 11-25 individuals per 150 ft. transect included crabs (*Cancer sp.*) and sponges (*Isodictya palmata*). Species noted in low densities (1-10) included lobster, sea stars (*Henricia sp.*), young of the year sculpin, skates, and burrowing anemones (*Cerianthus borealis*). Algal coverage was <1% for kelp and a thin diatom film was noted to be covering 25-50% of the pebble and sand substrate.

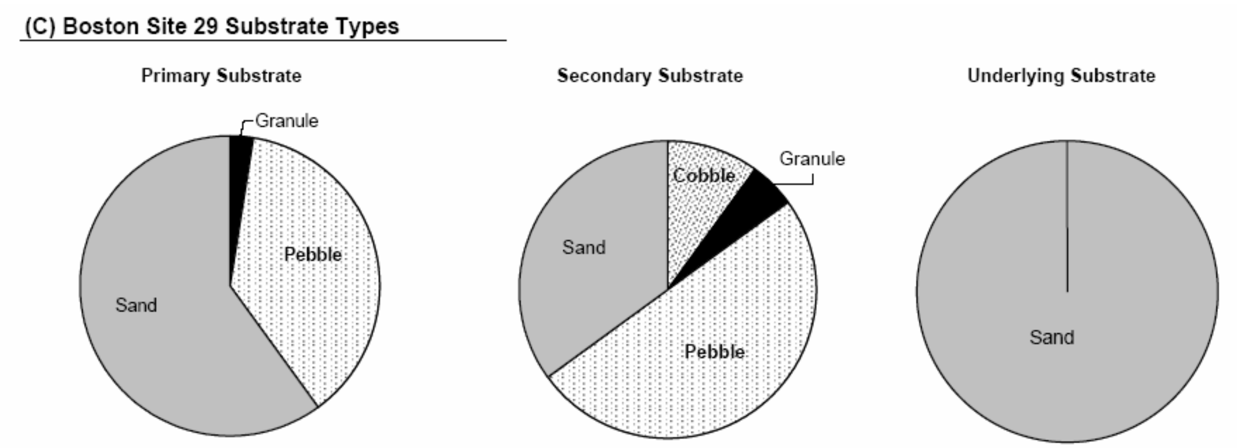

Figure 8: Substrate composition of Site 29 in Boston Harbor

In addition to these three potential sites, each site had a marked "shifting" zone around it. This shifting zone represented a margin for placement of the 0.59 acre enhancement area which would be utilized to move the reef if we discovered an area of high productivity or diversity that our initial surveys did not record.

After selecting these three sites, we determined if the sites would have the presence of a natural larval supply. We accomplished this using two different methods: (1) suction sampling natural sediments at both the potential reefs as well as nearby natural reefs and (2) deploying larval settlement collectors on the reef sites.

We wanted to suction sample each site in order to gather quantitative data on species present at the sites as well as presence/absence data on particular benthic and encrusting species and algae at each site. The suction sampling device consisted of a PVC lift tube supplied with air from a SCUBA tank (Figure 9). Samples were air-lifted into a mesh nylon bag attached to the upper end of the suction tube. We suction sampled six sites for comparison: the three potential reef sites, two nearby natural reefs, and the HubLine fill point near Site 29. At each site, ½ m^2 quadrats were haphazardly placed on the substratum at least 2m apart until a total of 12 replicates were completed at each site.

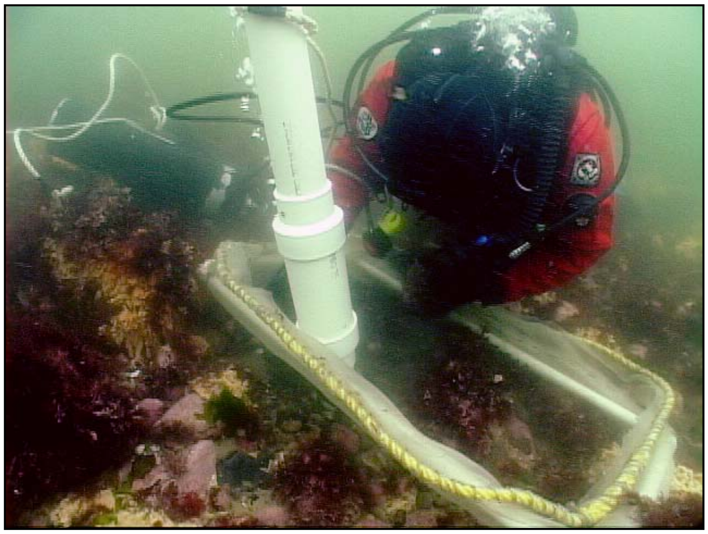

Figure 9: Diver suction sampling a 1/2 m^2 quadrat

All three potential reef sites were naturally lacking in prime larval settling habitat (cobble and boulder), and thus had naturally low larval settlement. Therefore, we designed ½ m^2 square mesh larval settlement collectors filled with cobbles and boulders to create temporary prime habitats within the area of the potential reefs. The collectors allowed us to determine if larvae would settle in these areas when provided with the correct habitat. Astroturf was placed on the bottom of each collector (for "underlying substrate") and covered with cobble and small boulders. With the assistance of contracted commercial lobstermen, 10 collectors were placed on each site. Collectors were deployed in July before larval lobster settling season in Massachusetts Bay and retrieved at the end of September, which was close to the end of the larval recruitment season.

Figure 10: (A) Lobstermen deploying settlement collectors, (B) Settlement collectors after two months underwater on site.

Once the collectors were retrieved, all flora and fauna were carefully inspected, counted and recorded on the surface. Larval crustaceans, such as young-of-the-year lobsters and crabs, were included in these counts. Species that were not readily identifiable in the field were preserved in alcohol and keyed out in the lab using a dissecting microscope.

Suction Sampling Results:
All three potential sites had no natural larval lobster settlement, although they did have a natural supply of other crustacean larvae (Figure 11). Overall, larval crustacean settlement was highest on the natural reefs, and lowest on the potential sites (Figure 11). We did record the presence of larval lobsters on both of the natural reefs and the HubLine fill point near Site 29. The suction sampling results also demonstrate that sites 29 and 23 had higher species abundance than Site 6 (Figure 12). However, Site 6 had higher species diversity than the other sites, and Site 29 had the lowest species diversity of all the sites (Figure 12). The two natural reefs had higher species diversity than all the other sites that were suction sampled. The HubLine fill point had the highest species abundance, although the species diversity was extremely low, consisting primarily of small whelks and crustacean larvae (Figure 12).

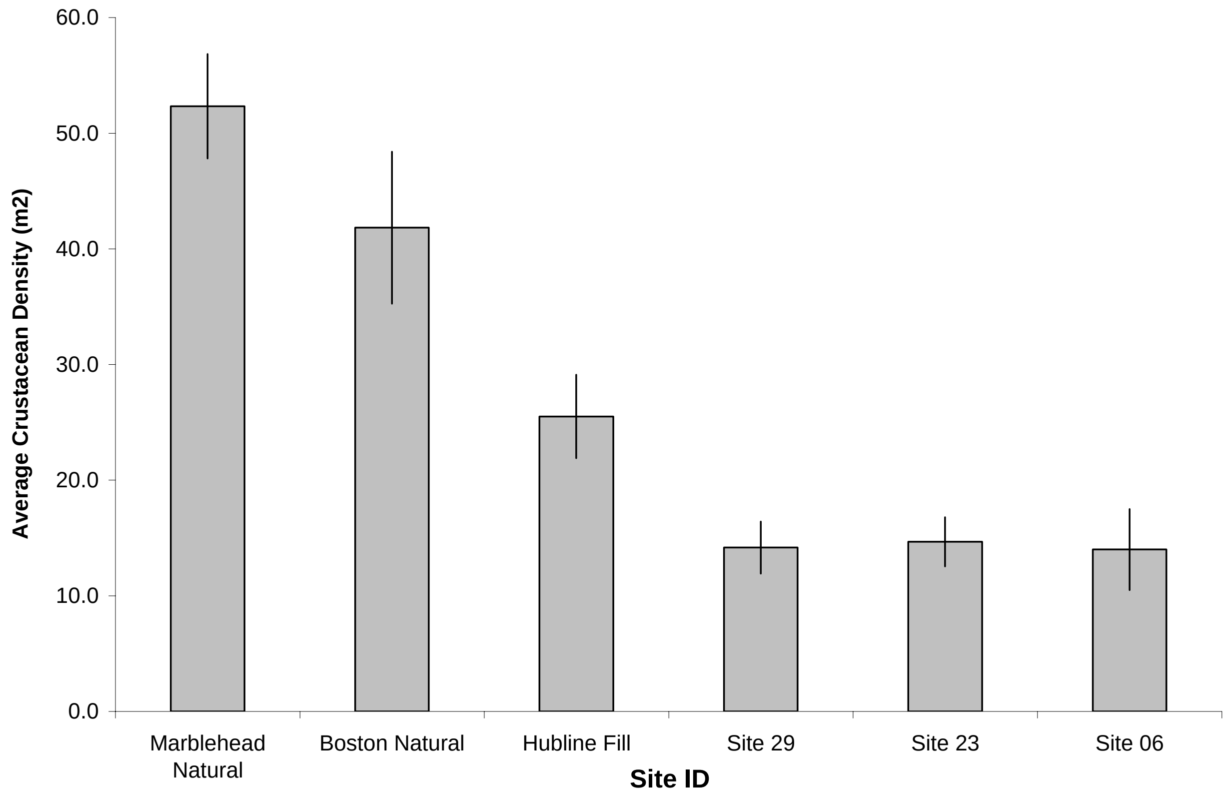

Figure 11: Mean density of all suction sampled crustaceans (including lobster) by site in 2005

Settlement Collector Results:
Results from the settlement collectors were also similar to the suction sampling. Our primary goal with the settlement collectors was to look for the presence or absence of lobster larvae, as well as evidence of settlement of other species. Site 29 and Site 6 had no larval lobster settlement, while Site 23 did experience lobster settlement. We did record, however, larval settlement for other fish and crustacean species on all three sites using the settlement collectors.

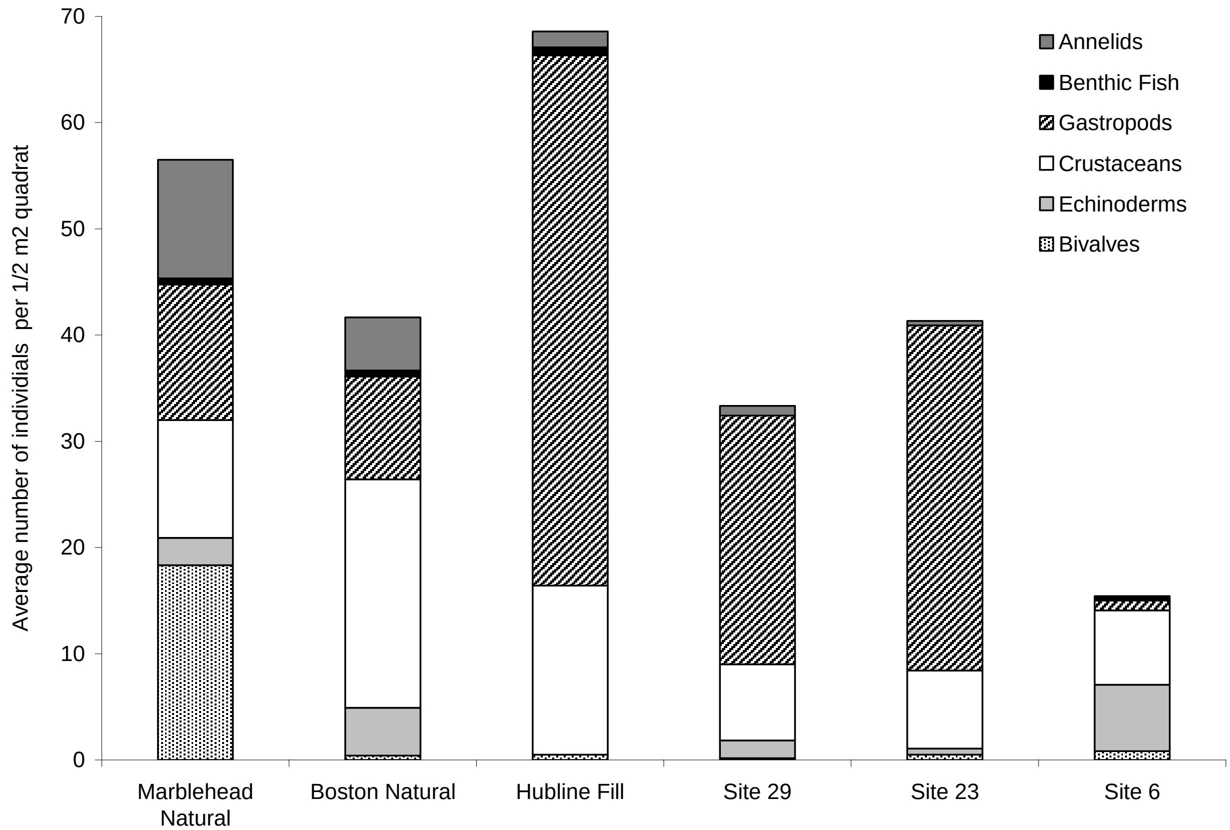

Figure 12: Mean number of individuals per suction sampled quadrat per site

We hypothesized that the lobster settlement at Site 23 was due to the high sedimentation rates we found in the collectors. This, most likely, made the collector “habitat” more preferential for larvae because it allowed larvae to excavate shelters under the rocks. However, it also indicated that if we placed an artificial reef at this site there was high potential for siltation and reef burial. Site 29 and Site 6 did not experience these high siltation rates in the collectors.

Despite the presence of larval lobsters, we eliminated Site 23 due to the high siltation rates and concern for reef burial. This left Site 29 in Boston Harbor and Site 6 in Marblehead as the final sites considered for the reef. Both sites had no larval lobster settlement in their collectors, yet the suction sampling results from the natural reefs adjacent to these sites demonstrated that larval lobsters were present near the sites. Additionally, Site 29 was within 10m of the suction sampled HubLine fill point area, which also experienced larval lobster and crustacean settlement. Thus, we concluded that although larval lobsters were not present in the settlement collectors, we could expect larval lobster settlement on either of these sites.

We also wanted to consider overall species abundance and diversity at these two sites in order to select the site with the lowest natural species abundance and diversity. We ran three species diversity analyses on the suction sampling data in order to confirm our observations that Site 29 had lower species diversity than Site 6 (Figure 12). When comparing only the results from Site 29 and Site 6, all three analyses (Shannon-Weiner, Simpson, and JackKnife) demonstrated that Site 6 had the higher measure of species richness and Site 29 had the lower measure of species diversity.

Table 3: Results of species diversity analyses by site from suction sampling data. Lower values indicate lower diversity.

	Marblehead Natural	Boston Natural	HubLine Fill	Site 29	Site 23	Site 6
Species count	26	21	12	9	15	24
Individual count	677	496	818	408	496	186
Shannon-Wiener Diversity Index	2.221	1.988	0.943	1.032	0.987	1.917
Simpson	0.844	0.826	0.438	0.489	0.418	0.764
JackKnife	29.667	25.583	15.667	10.833	18.667	30.42

Site 29 clearly met the majority of the site selection criteria, as opposed to Site 6. Site 29 was the closest to the HubLine, the closest to a HubLine fill point, received little wave action, had no slope, was at a good depth (31 ft. MLW), had low species diversity and abundance, had a natural larval supply, and would be more cost effective than Site 6 (based on contractor bids) (Figures 13 & 14).

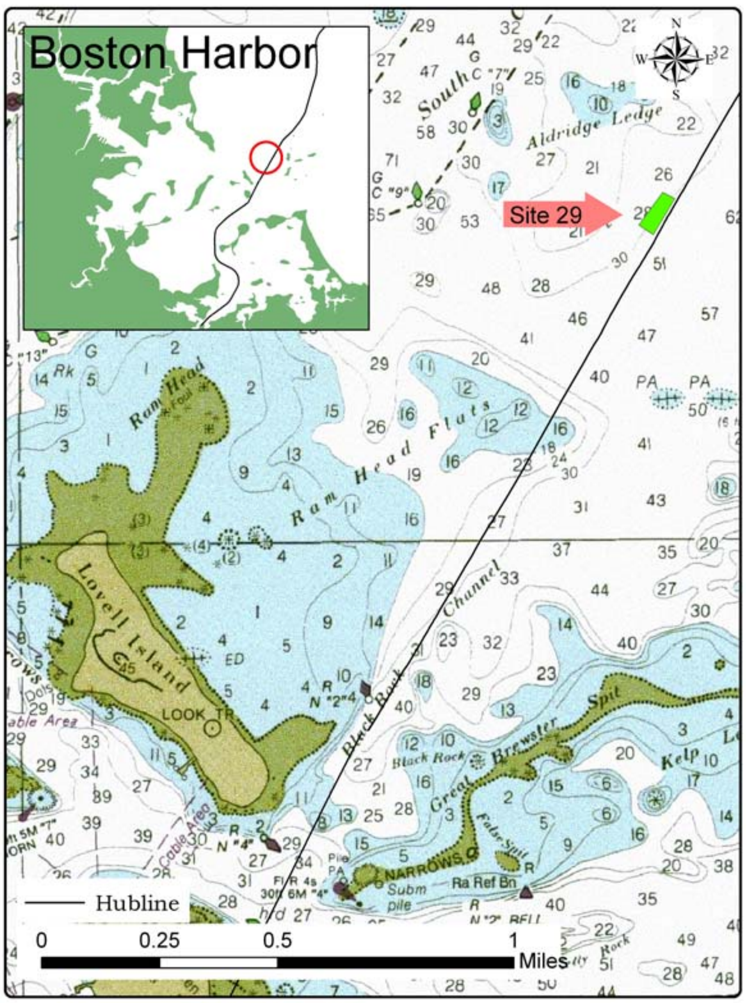

Figure 13: Habitat enhancement area, Site 29, in Boston Harbor

Figure 14: View of Site 29 from the surface with Calf Island in the background

<u>Site Survey</u>: Prior to the start of construction, *MarineFisheries* collaborated with USGS to collect georeferenced multibeam data on Site 29 and the surrounding area. The results of the survey confirmed the results from our substrate survey dives and showed that Site 29 was a non-descript, flat area with little to no hard bottom habitat (Figure 15). The survey also allowed us to confirm the location of the HubLine and the cobble fill point near Site 29. Additionally, the survey verified that the reef would be near naturally occurring hard bottom areas (Figure 16). We assumed that naturally occurring hard bottom areas could provide the artificial reef with new juvenile settlers and potentially attract adults.

<u>Reef Construction:</u>
Upon completion of the site selection process *MarineFisheries* solicited bids from independent contractors for reef construction. After meeting with RDA Construction to discuss methods and costs, we selected RDA Construction Corp. as our general contractor.

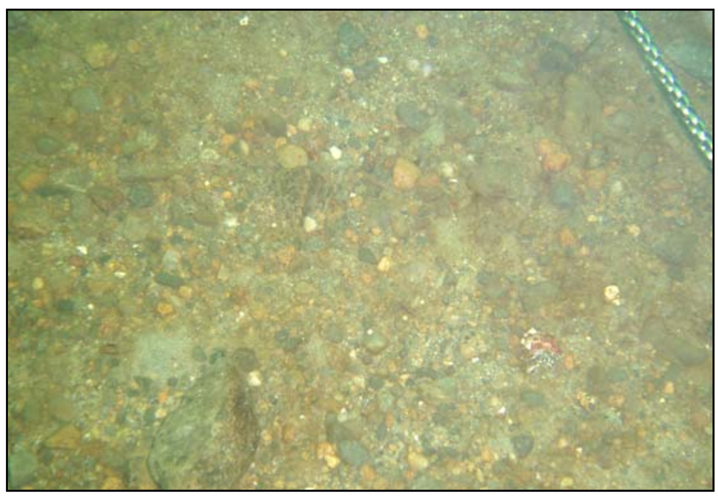

Figure 15: An example of the substrate found at Site 29 (sand and granule)

We established in the contract that RDA would be responsible for obtaining clean reef materials from local quarries. The quarry rocks were blasted cobble and boulder. All rocks had to be cleaned of silt and sediment outside of coastal resource areas prior to transportation and installation. We expected at least 95% of the cobble and boulder material to be within one of the four specified size categories. *MarineFisheries* independently inspected reef materials to ensure adherence to rock size specifications prior to deployment on the site. In addition to deploying the reefs accurately and according to our dimensions, RDA Construction was also responsible for transporting all materials to the site and coordinating a post-construction side-scan sonar survey. According to the contract, *MarineFisheries* was responsible for obtaining all necessary permits and conducting independent surveys to verify correct reef placement.

MarineFisheries required that construction start by March 1st, 2006 and be complete by April 15th, 2006 in order to comply with time-of-year (TOY) construction limits that are normally assigned to marine construction projects in Massachusetts Bay. These TOY limits were not actually assigned to *MarineFisheries* in the permitting process; however, because we are a state environmental agency, we self-imposed these TOY work windows in order to avoid impacting aquatic resources and habitat. Winter construction also minimizes user conflicts because lobstermen generally fish less intensively in the winter. Construction in March and April would also allow for the reef to develop significant invertebrate and algal growth during the spring of 2006, which could encourage larval lobster and finfish settlement on the reef during its first year of deployment. Another advantage of winter construction was that it could minimize impacts to spawning migrations of finfish and periods of shellfish and lobster spawning activity.

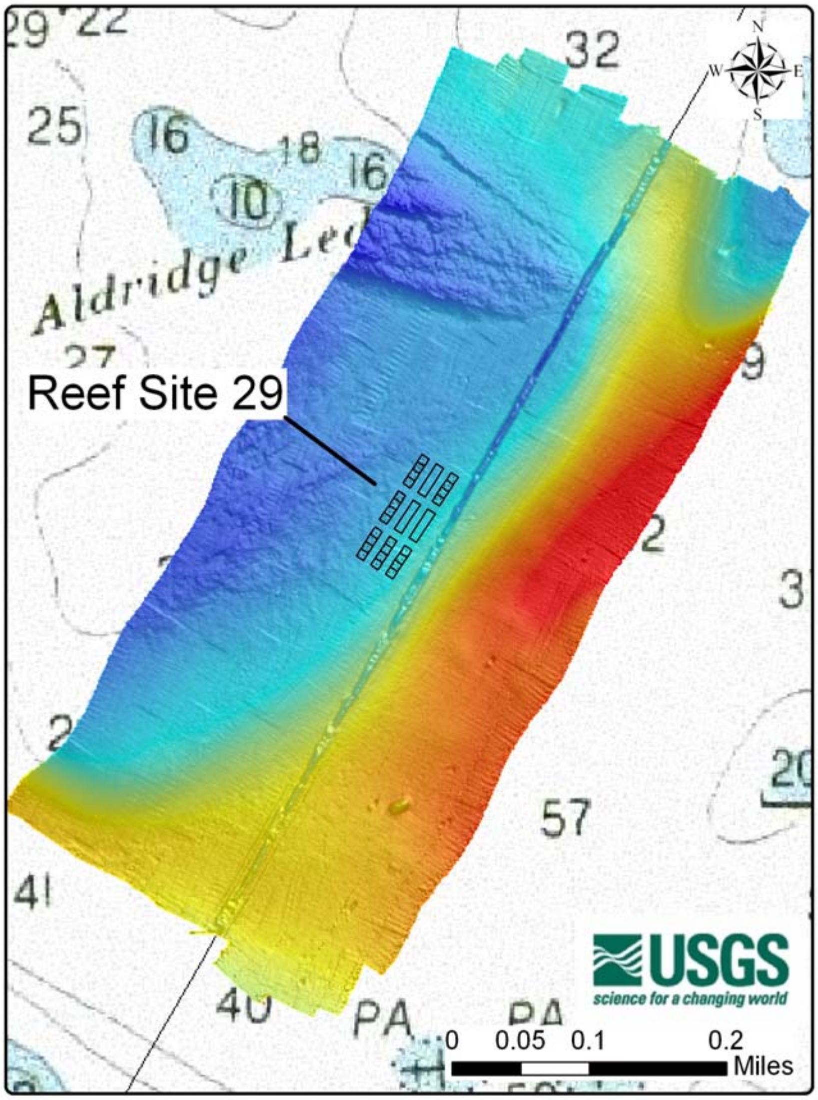

Figure 16: Multibeam and side scan sonar survey results from a pre-construction survey. The reef area is shown over the survey data.

Construction required the precise placement of rocks by size within each reef footprint. Originally, each of the six reefs had four different rock sizes separated into 10*10m sections. The rocks were going to be separated by size, and arranged in a graduated fashion within each plot so that each rock size would contribute equally to the total placement area. The cobble-sized rocks were to be installed with two layers and the boulder-sized rocks were to be installed in a single layer. According to RDA Construction, there were two ways to build the reef: (1) using a crane and a barge or (2) using a dump scow. The crane and barge method would have allowed for extremely accurate placement and layering of the rocks, providing *MarineFisheries* with a final product that conformed exactly to our original construction plans. The dump scow would allow us to build the reef according to the desired dimensions (40*10m for each reef) for less money, however the layering and placement of the reefs would be slightly less accurate. Additionally, the dump scow had six pockets and due to loading safety requirements, each of the six pockets needed to be filled with stone so that the rock weight would be evenly distributed throughout the barge. Thus each reef unit would have six smaller sections of the individual rock sizes rather than our proposed four rock size sections. Due to budget constraints, we decided to have RDA Construction use the dump scow construction method. Therefore, the reef design had to be slightly modified in order to accommodate the loading requirements of the six sections within the dump scow (Figure 17). Rather than four 10*10m units (which combined together to create a 40*10m long reef), we had six 6.6*10m units that still combined together to meet the 40*10m required reef dimension.

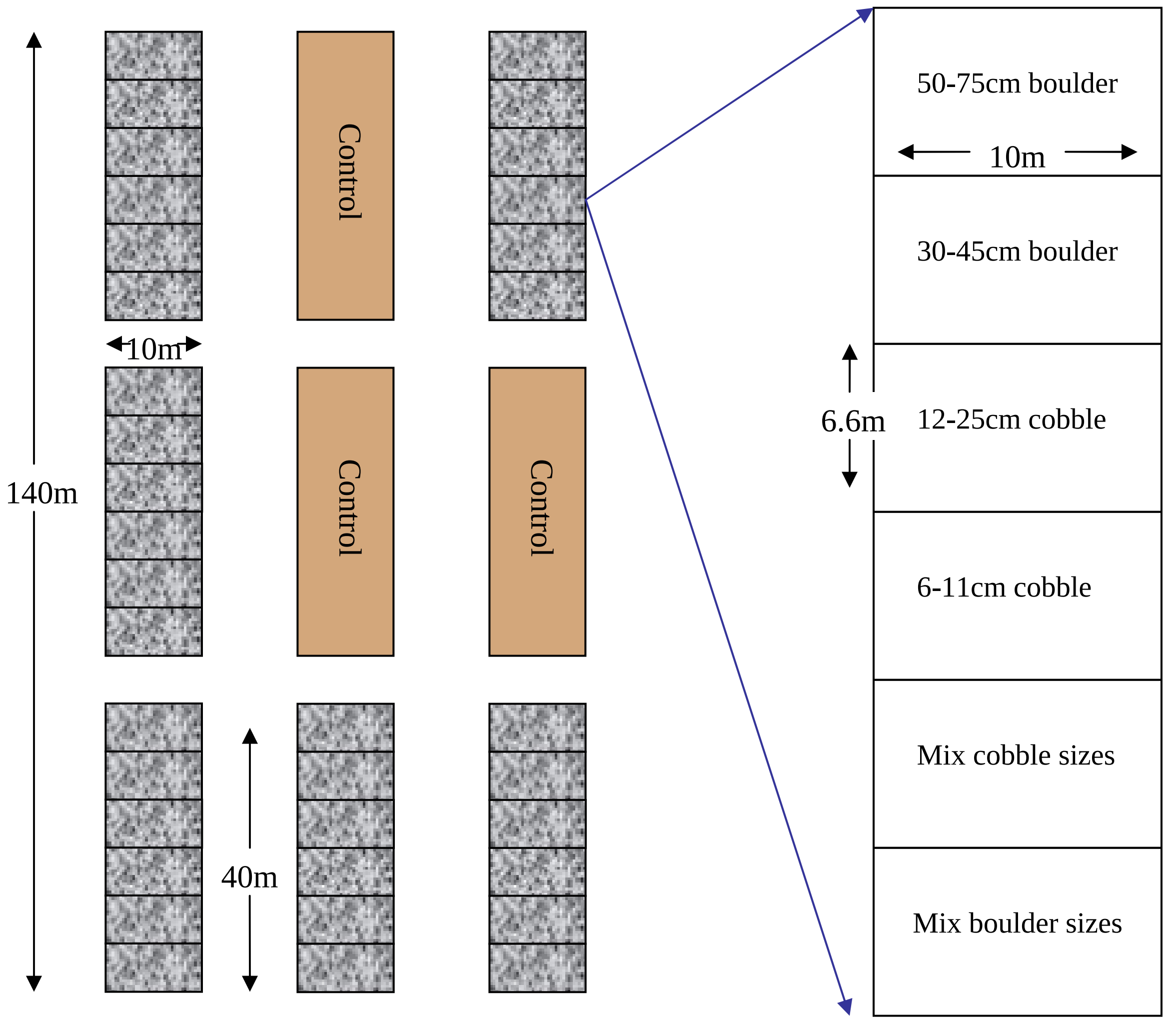

Figure 17: New reef dimensions updated to accommodate dump scow dimensions

Therefore, we assigned the following rock sizes to each of the six sections: (1) 50-75cm boulders, (2) 30-45cm boulder, (3) 12-25cm cobble, (4) 6-11cm cobble, (5) mix of 6-11cm and 12-25cm cobble, and (6) mix of 30-45cm and 50-75cm boulder (Figure 17). We felt that these small changes would not affect the success of the reef due to the fact that the overall reef dimensions would be the same and the rock sizes necessary to target different life history stages of marine species would also still be the same.

Construction activities began in early March. *MarineFisheries* employees monitored all construction activities to ensure compliance with permit requirements (clean rocks, etc.). We conducted site visits to RDA Construction's staging area to measure the rocks and check the cleanliness of rocks. It became clear that RDA would meet our rock dimension requirements for all rock sizes but the largest boulders. Due to the delays caused by various problems that RDA encountered and the need to begin construction immediately, we concluded that the larger boulders were not going to compromise the value or function of the reef. In fact, the larger rocks would most likely create more relief and potentially attract more fish to the reef area than the rock sizes we had originally planned. All rocks met our requirement for cleanliness prior to construction.

The first reef was constructed March 23rd and the five remaining reefs were built in the following weeks. The last reef was dropped on April 11th, and construction was considered to be complete at this point. Throughout the construction period, *MarineFisheries* divers continued to inspect each reef after it was dropped on site. All dimensions were within 25% of the original specifications and the reefs were accurately placed according to the coordinates provided for each reef. Overall, *MarineFisheries* is extremely satisfied with the final structures.

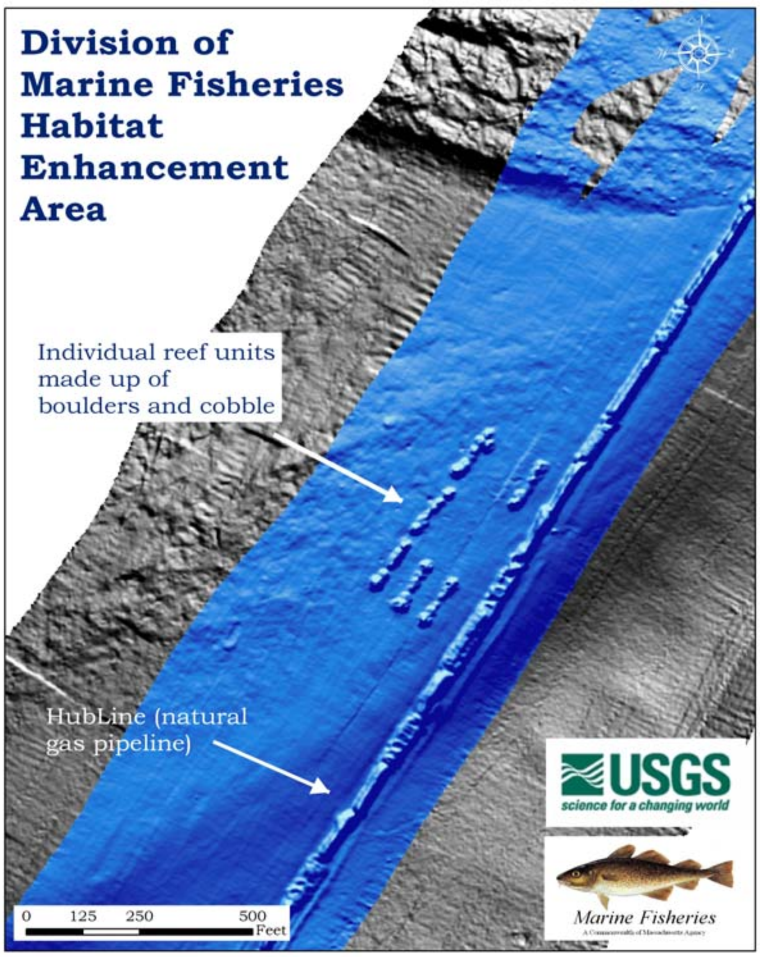

Figure 18: Multibeam image of the reef

A side scan sonar survey was completed by the contractor on May 8, 2006 and these results have been received by *MarineFisheries*. A second survey, conducted by *MarineFisheries*, was completed in July 2006 in order to obtain post-construction multibeam data from the site (Figure 18).

<u>Monitoring Program:</u>
MarineFisheries initiated the monitoring process as soon as the reef construction was complete. To evaluate the success of the reef project, we designed a structured monitoring program to characterize and track larval settlement, as well as the development of invertebrate and finfish populations on the reef. This program includes seasonal visual dive surveys along permanent transects, semi-annual small fish trapping, annual larval suction sampling, a ventless trap survey, optical/acoustical surveys, and potentially other small scale scientific studies. Most of these

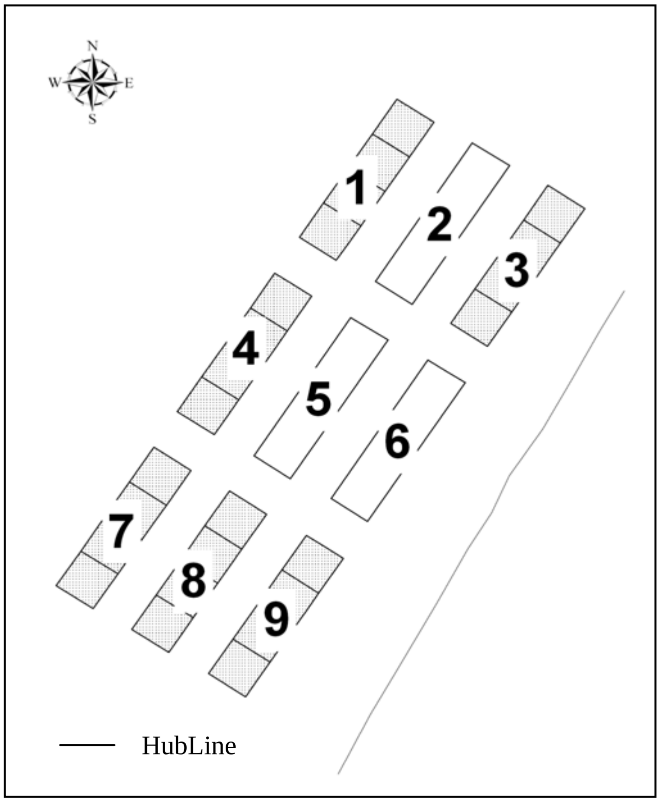

Figure 19: Assigned ID numbers for reefs and control areas

programs began in May 2006, although the visual dive survey and permanent transect sampling began in the fall of 2005.

We assigned unique numbers to each reef and sandy control unit in order to facilitate the process of identifying individual reefs (Figure 19). Throughout the remainder of this report and future reports, the reefs and control units will be referred to with these unique numbers.

Visual Dive Surveys - We established five of permanent transects prior to reef construction in order to document any changes in habitat and species abundance and diversity post-reef installation. Since construction completion, divers have finished setting up all the transects including: 6 artificial reefs, 3 sandy control sites near the artificial reefs, 2 HubLine cobble fill points, and 3 natural rocky reefs. The natural rocky reef transect that was established in 2005 near Lovell Island was moved to a deeper, nearby location in the spring of 2006 due to the need to compare the artificial reef to a natural reef at a similar depth.

The permanent sampling methodology allows us to repeatedly sample the same transects over time. When divers are not working on the transect, no transect line is actually left on the seafloor. Rather, we permanently mark the start and end points of the transect and use a known compass bearing to set the transect tape down on the same area each time we need to collect data. We use 2m long "swath" bars to quantify macroinvertebrates and fish along the transect. We use 1m^2 quadrats with a 1/4 m^2 inset quadrat to sample smaller invertebrates typically found in higher densities (e.g. *Modiolus sp*.), substrate type, algal coverage, and encrusting or sessile invertebrate coverage (e.g. colonial tunicates or sponges). These methods will allow us to actually quantify changes in species abundance and diversity through time. In order to make comparisons across seasons, we hope to sample the permanent transects four times a year. These data will be presented in the 2007 report after a full year of monitoring is complete.

Permitting Process:

MarineFisheries completed the permitting process prior to the start of any construction activities.

Permits:

- Town of Beverly Order of Conditions (DEP File # 5-875)

    - Official letter sent to Beverly notifying them that the final site selected for this process was not in Beverly waters
- Town of Marblehead Order of Conditions (DEP File # 40-836)
    - Official letter sent to Marblehead notifying them that the final site selected for this process was not in Marblehead waters
- City of Boston Order of Conditions (DEP File # 006-1035)
    - Official letter sent to Boston notifying them that the final site selected for this process is in their waters
- Massachusetts Environmental Policy Act (MEPA) approval (File # 13605)
- Department of Environmental Protection Water Quality Certification (DEP # W066080)
- Department of Environmental Protection Chapter 91 License (DEP # W05-1421)
- U.S. Army Corps of Engineers

<u>Public Awareness and Outreach Activities:</u>

Scientific Conferences:

- Sea Grant Science Symposium, Narragansett, RI, 2005: Lobsters as Model Organisms for Interfacing Behavior, Ecology, and Fisheries. Presented poster entitled: "Using GIS to Select Potential Sites for Habitat Enhancement in Massachusetts Bay."
- Geographic Information Systems and Ocean Mapping in Support of Fisheries Research and Management Conference, MIT Sea Grant, April 11, 2006. Coauthored a poster entitled: "Benthic Habitat Mapping at Mass DMF: Focusing on Better Fisheries Science and Management"

Public Talks/Outreach:

- Worked with home-schooled children, through the Family Resource Center, to educate them about local marine life and the Habitat Enhancement Project in Fall 2005
- Boston Harbor Lobstermen's Association, January 11, 2006
- Massachusetts Lobstermen's Association, February 3-5, 2006
- Quincy Coastal Commission, February 21, 2006
- Boston Sea Rovers, Boston, MA, 2006: "Dropping Rocks! How the Division of Marine Fisheries Selected a Site for Habitat Enhancement"
- American Fisheries Society, Lake Placid, NY, September 11-14, 2006: "Dropping Rocks! How the Division of Marine Fisheries Selected a Site for Habitat Enhancement"

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